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FROST DEPTH IN FOREST SOILS NEAR JUNEAU, ALASKA

by

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INTRODUCTION

Freezing drastically changes soil-water relations. During freezing, water crystallizes to ice, setting up tension and thermal gradients and pulling water from surrounding moist soil. Other frost effects include changes in soil structure, rupture of plant tissue, and redistribution of soil moisture. Frost-heaved seedlings are a consequence of ice crystal growth well known to foresters. Pierce, Lull, and Storey (1958)[1] recently summarized American literature on forest soil freezing showing, in addition, the generally ameliorating effects of forest litter and canopy on soil freezing in forests of Northeastern United States. Frost penetration has not been measured in old-growth western hemlock-Sitka spruce forests, widespread over southeast Alaska. Although limited in scope, the following frost measurements help fill this gap in the forest literature of southeast Alaska and add to our knowledge of water behavior in local forest soils.

THE STUDY AREA

A small logging operation 5 miles north of Juneau provided a convenient study area. Typical of the region's old-growth forest, the stand was about 80 percent western hemlock, 20 percent Sitka spruce. Trees ranged in height from 75 to 120 feet, in diameter from 18 to 48 inches, with basal area about 250 square feet per acre. The logged

[1] Names and dates in parentheses refer to Literature Cited, p. 7.

area was clearcut 3 years ago, leaving much slash scattered about, but the litter-covered forest floor was little disturbed. A primitive logging road (fig. 1) was built on bare soil and maintained more or less snow-free by logging throughout the period of frost observation.

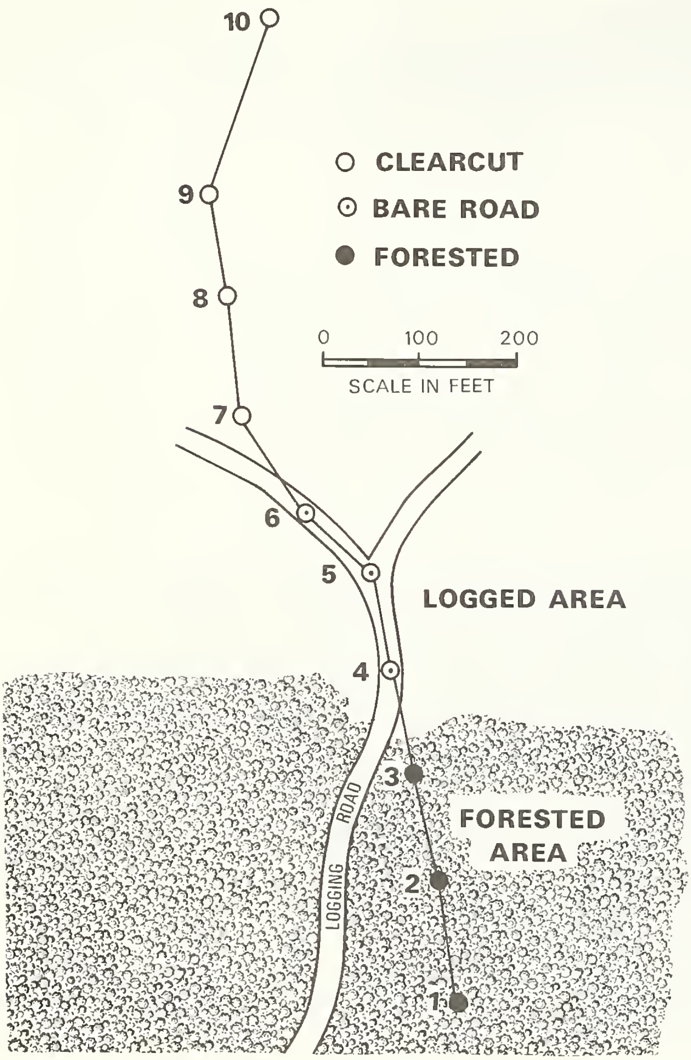

Figure 1.--The study area.

The soil is well-drained Tuxekan[2/] loam gently sloping about 10 percent northwest. A 6- to 8-inch layer of moss and litter covers a bleached, gray A_2 horizon 1 to 2 inches deep. An 18- to 24-inch B horizon is splotchy, reddish brown, and iron stained, overlying loose, water-deposited sand and gravel.

[2/] Tentative name pending final correlation by the U.S. Soil Conservation Service.

METHOD

A plot transect was established as shown in figure 1, permitting frost sampling over a course of similar soil and slope. Starting on November 12, 1965, depth of soil freezing was observed at biweekly intervals during periods of rapid change, at monthly intervals during cold weather. Frost depths were observed by scraping away moss and litter, then digging through the frozen mineral soil with mattock and shovel. Because both the upper and lower frozen soil surfaces were irregularly shaped and the mattock holes much wider on top than bottom, frost depth measurements were approximate although recorded to the apparent nearest inch. Observations ended on May 14, 1966.

Mean daily air temperatures were published by the U.S. Environmental Science Services Administration (1965-66) for the climatic station at Juneau Airport, 3 miles west of the study area. These data indicate a colder than normal winter; e.g., mean monthly temperature for January was only 8.6° F. compared with the normal of 25.1° F. for the airport.

RESULTS

Frost measurements are shown in table 1. Despite the probability of sampling error, depths of freezing are consistent among cover types. Measurements of December 3 on the road and of February 2 on the clearcutting showed the only variation greater than 4 inches within cover types. Temperature at the airport and depths of frost and snow on the study area are shown in figure 2. These sampling sites were selected as representative of data from forest, clearcut, and road stations. Note that during November and December soils froze rapidly in the bare road, less rapidly on clearcut plots. The forest plots froze very little, then thawed completely during warm weather in mid-December. During this early winter period, concrete frost (Post and Dreibelbis 1942) formed in the road, honeycomb frost in forested and clearcut soils. Granular frost (Hale 1950) was always found in litter above frozen mineral soil but was not included in these data.

Snow accumulation also influenced frost formation. Concrete frost quickly moved deeply into road plots, most of which were maintained almost snow-free throughout the winter. Maximum frost depth was not measured in the stony, frozen, road soil, but freezing to 18 inches was noted in nearby road construction. Deepest freezing was expected in roads, Kersten (1949) having observed that thermal conductivity of Alaska soils increases with density. Interception losses of snow were evidenced by lesser accumulations on forest plots (fig. 2). Note that heavy snow accumulations terminated frost penetration. Honeycomb frost was noted in forested and litter-covered plots on December 17; concrete frost, in all plots on December 30 and thereafter. Although air temperature increased steadily after mid-January, it remained below freezing until mid-March. During this time, insulation by snow maintained

Table 1.--Thickness of frozen soil near Juneau, Alaska, during the winter of 1965—66

Cover	Station	Nov. 12	Nov. 17	Dec. 3	Dec. 17	Dec. 30	Jan. 10	Feb. 2	Feb. 25	Mar. 26	Apr. 4	Apr. 29	May 9	May 14
		Inches												
Forested	1	0	1/2	0	0	10	12	15	12	5	10	1/ 5	1/ 3	0
Forested	2	0	1/2	1-1/2	0	8	11	15	8	6	6	1/ 9	1/ 4	0
Forested	3	1/2	1	1/2	0	6	12	11	12	8	8	1/ 6	0	0
Bare road	4	1	8	11	(2/)	--	--	--	--	--	(3/)	(4/)	0	0
Bare road	5	0	7	6	(2/)	--	--	--	--	--	(3/)	(4/)	(5/)	0
Bare road	6	0	8	1	1	>8	(2/)	--	--	--	(3/)	(4/)	(5/)	0
Clearcut	7	0	2	2	1/2	8	12	16	15	9	8	0	0	0
Clearcut	8	1	4	4	2	8	8	10	12	--	6	0	0	0
Clearcut	9	1	5	5	4	7	12	18	12	10	9	1/ 5	0	0
Clearcut	10	1	2	5	3	8	12	--	--	--	--	1/ 1	0	0

1/ Frozen soil thawing on both surfaces.

2/ Road surfaces frozen, partly cleared of snow, used for logging. Frost depths were not measured when roads were in use.

3/ 3 inches of mud overlying soil frozen to unknown depth.

4/ 14 inches of mud overlying soil frozen to unknown depth.

5/ 16 inches of mud overlying soil frozen to unknown depth.

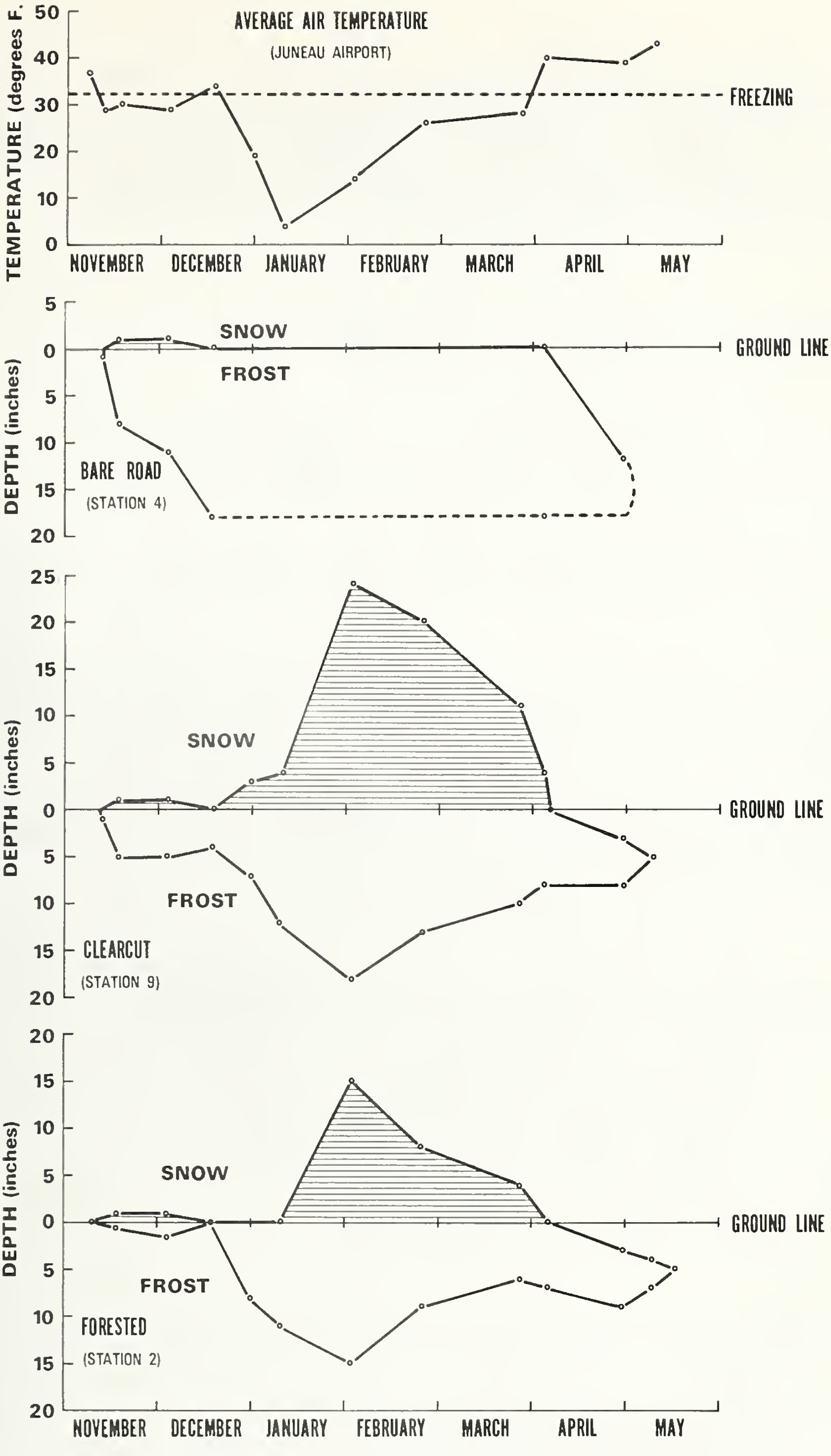

Figure 2.--Air temperature, snow accumulation, and depth of soil freezing under three conditions of soil cover.

subfreezing conditions on the upper soil surface, but heat from within the earth thawed the lower frozen surface as reported from Wisconsin by Bay et al. (1952). During late March and early April, thawing temperatures occurred almost daily, snow melted, and concrete frost became a loose mass of ice crystals in a matrix of saturated soil. This condition persisted into May on all plots.

DISCUSSION

Although these results were obtained on a small area, other observations verify that they were representative of frost conditions in well-drained soils in the Juneau vicinity. Water pipe and road excavations near the study area revealed soil frozen from 16 to 18 inches in January. Frost disappearance in neighboring areas also coincided with study results. Late in March, the Alaska Highway Department imposed load limit restrictions due to road base thawing. Ponds of snowmelt water drained away at this time. Nevertheless, isolated patches of concrete frost were found under forest trees until mid-May when all soils finally thawed.

The insulating effects of litter and canopy, widely proclaimed in forestry literature, are apparent in these data. Insulating effect of litter is evidenced by soils freezing and thawing more rapidly on roads than on clearcut plots. Canopy insulation was demonstrated on forest plots by least rapid snowmelt, slowest rates of soil freezing and thawing, and least depth of frozen soil. A tabulation from Thorud (1965) shows similar insulating effects of snow and litter in the colder winters of Minnesota:

Soil treatment	Freezing depth (inches)
Natural oak forest	34
Soil compacted	36
Litter removed	39
Without snow	47
Soil compacted without snow	52

It has been suggested that greatly increased frost penetration after logging might change water relations, structure, or other soil properties, possibly influencing the landslide problem reported by Bishop and Stevens (1964). It now seems unlikely that clearcut soils can be expected to freeze much deeper than forested soils. In this study, frost penetrated only 4 inches deeper on clearcut than on forested plots. Even less difference seems likely during warmer winters characteristic of the region.

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